Demonstration of Expected BPM Closed Orbit Resolution in Tevatron

Bob Webber January 13, 2004

This note presents data indicating the expected closed orbit resolution of the BPM signal processing hardware planned for the new Tevatron BPM system. No representation is made regarding absolute accuracy or p/pbar signal separation capability.

Data in Figure 1 was obtained during proton loading of unsuccessful Collider Store #3040 on Saturday, Jan. 10, 2004. All other data was acquired during the 36x36 Collider Store #3148 on Sunday, Jan. 11, through Monday, Jan. 12, 2004. All data are the results of processed signals from the proton end of BPM vertical A14 with no attempt to de-convolve any contamination from antiproton signals.

All data was obtained through a "Recycler" BPM system installed in Tevatron house A1 using a Recycler style EchoTek ECDR-GC814 digital receiver card processing Tevatron 53MHz beam signals with a final bandwidth of about one kilohertz. The digitizer clock was phase-locked to 7/5 times the Tevatron RF frequency, ~74MHz.

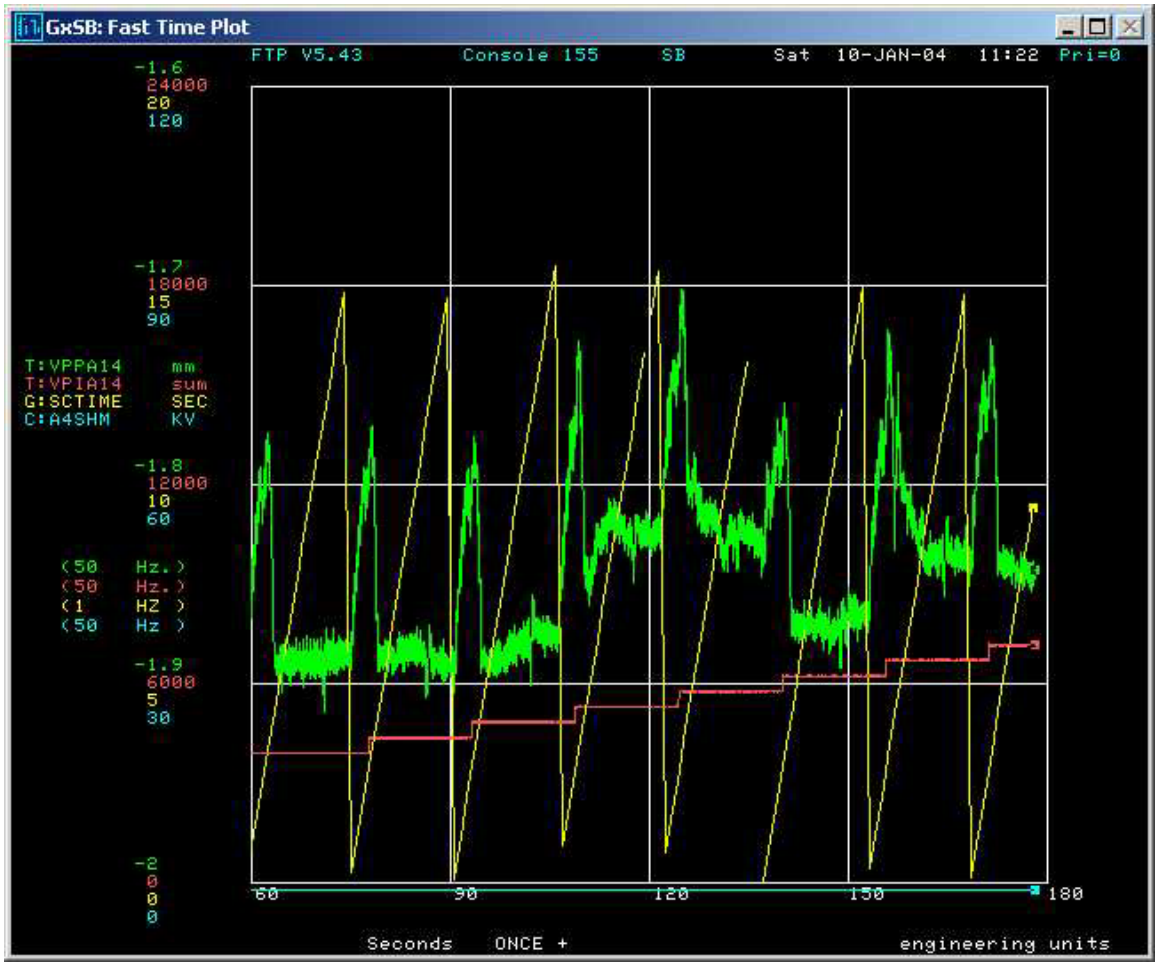

Figure 1. Proton Loading, Store #3040. Vertical A14 measured position (green, 0.1 mm/div.), vertical A14 BPM sum signal (red), and supercycle time (yellow).

Figure 1 shows the position measurement results during proton loading. There are about 20 proton bunches in the ring at the start of the plot and seven more injected during the time shown. Beam motion of about 0.1 mm is observed at injection time of each supercycle. This is correlated with a proton injection orbit bump that is intended to be local and not span A14. Clearly there is residual orbit distortion at A14. (This has been observed with independent measurements in the past.) The figure indicates a resolution of roughly 10 micrometers. The apparent slow variation of beam position over the length of the plot is neither understood nor corroborated by any independent measurement; it is not know whether this is real beam motion or an instrumental error.

A quantitative measure of the closed orbit resolution of the system is available from data-logger data from Store #3148. The 1 KHz bandwidth position data is data logged at 1 Hz. Figure 2 shows the logger data for the VA14 position measurement during loading and beginning of that store.

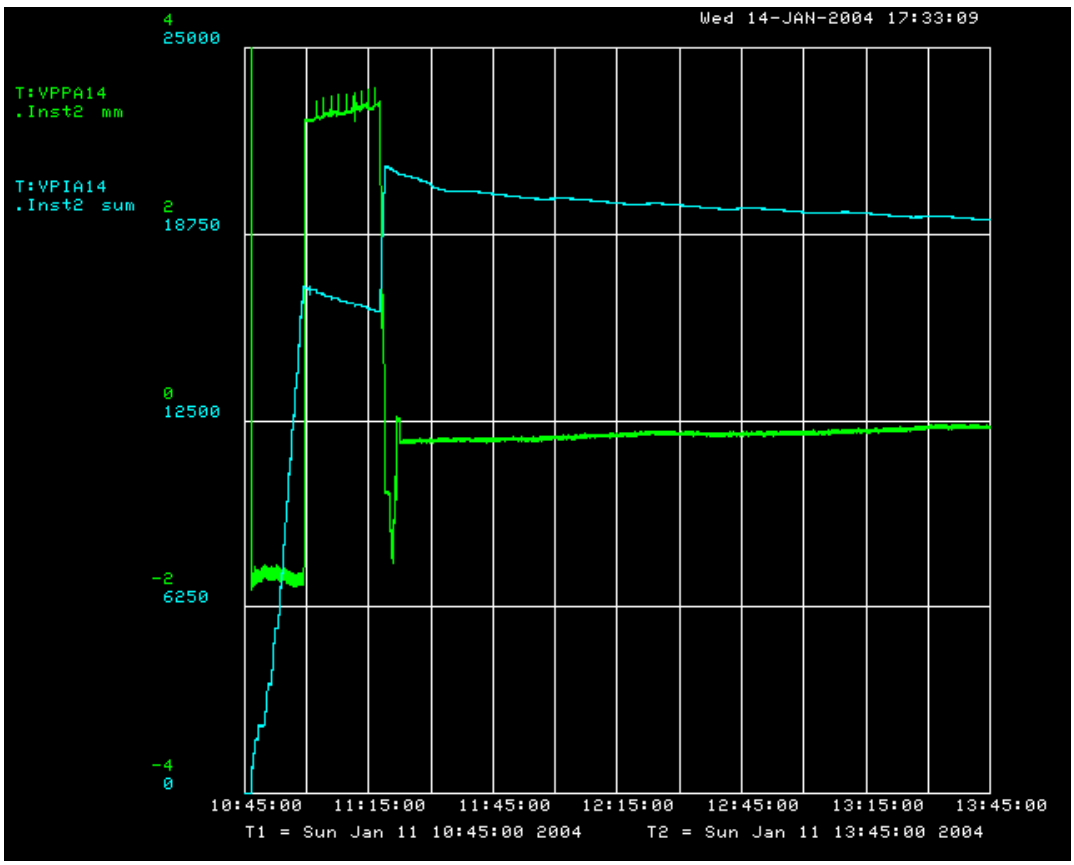

Figure 2. Loading and Beginning of Store #3148. Vertical A14 measured position (green, 2 mm/div.) and vertical A14 BPM sum signal (blue).

Relatively stable position during proton loading is observed, followed by opening of the helix, injection of pbars, acceleration, low-beta squeeze, transition to collision helix, and about the first 2 ½ hours of the store. The apparent 0.1 to 0.2 mm motion during antiproton loading might be real motion or it might be due to contamination of the proton signal by increasing number of antiprotons. This requires further investigation.

Figure 3 shows the same parameters for the duration of Store #3148. Again, the slow apparent 0.1 to 0.2 mm motion during the ~22 hour store cannot be confirmed as either real motion or instrumental drift. Comparison of data from several monitors around the ring is needed to understand this signal.

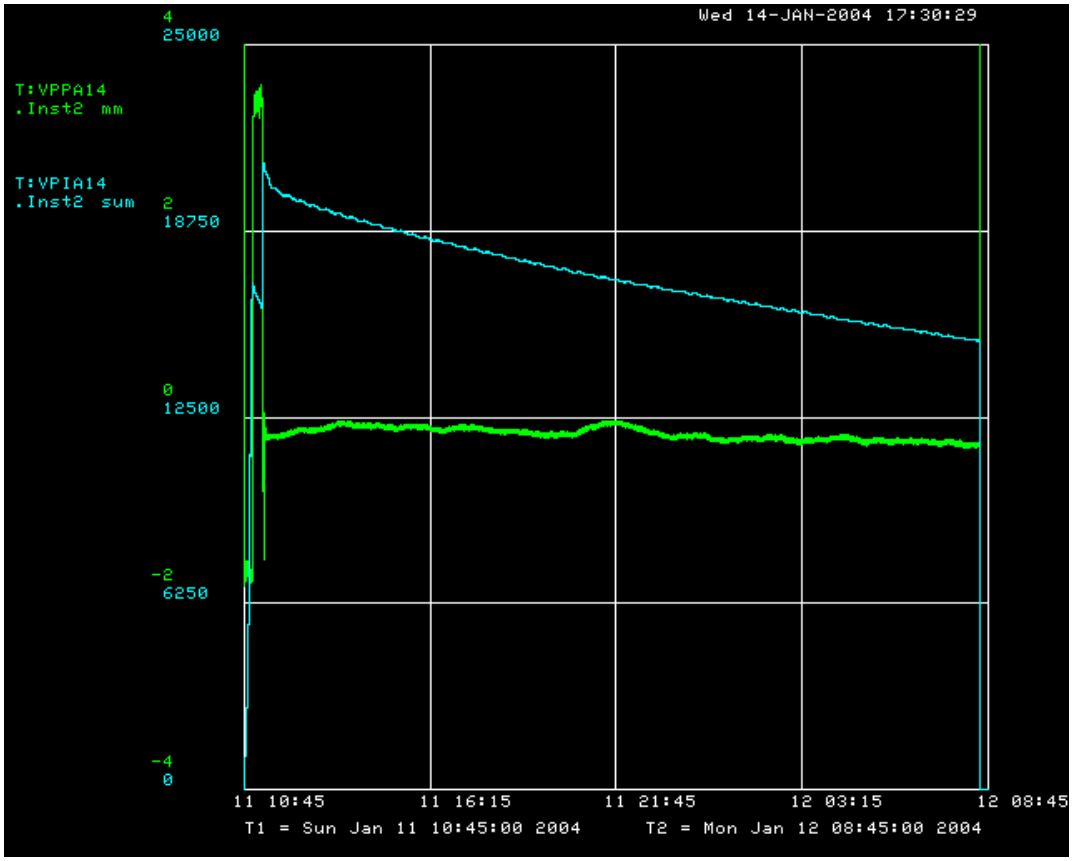

Figure 3. Duration of Store #3148. Vertical A14 measured position (green, 2 mm/div.) and vertical A14 BPM sum signal (blue).

The same data plotted on sensitive scales for one-hour periods early and late in the store are shown in Figures 4 and 5 respectively. These intervals have been analyzed to obtain quantitative estimates of orbit measurement resolution. Standard deviations of the data over each of the full one-hour periods and for each 5-minute interval of the two periods are shown in Table 1. The final entry in each column shows the average and the standard deviation of the 12 standard deviations.

All results indicate short-term (5 minute) orbit measurement resolution in the 8-9 micron range in 1 KHz measurement bandwidth, even including any real beam motion that might be present at that level. There is good reason to believe that closed orbit resolution of 7 microns in a 10 Hz bandwidth specified in the Tevatron BPM requirements document will be achieved.

Turn-by-turn resolution and ability to cleanly separate proton and antiproton signals remain to be demonstrated.

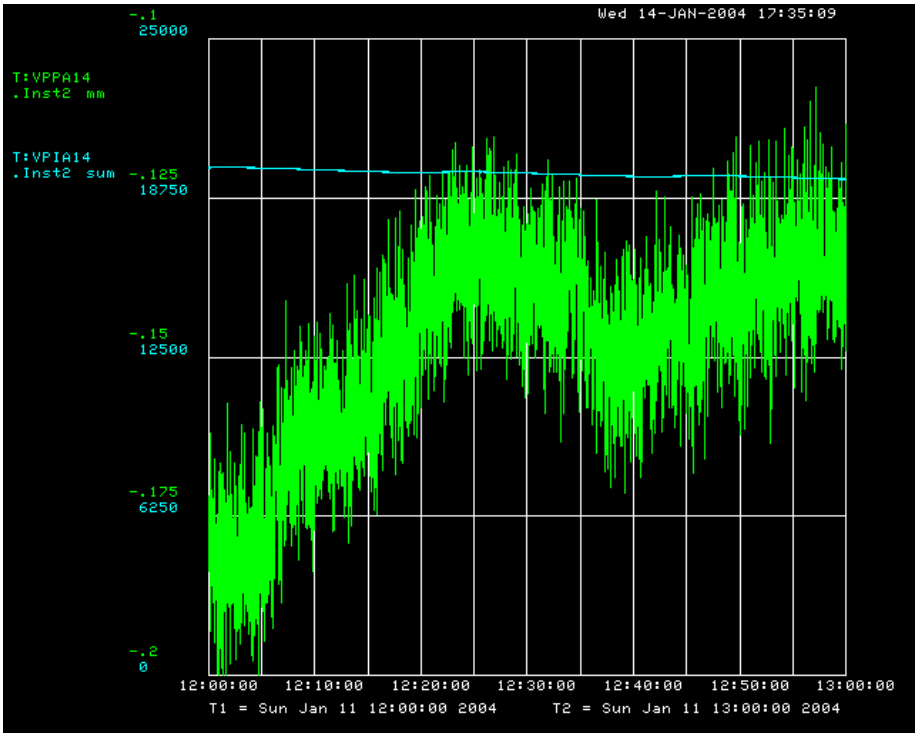

Figure 4. One hour of data, ~1 hour into the store. Vertical A14 measured position (green, 2 mm/div.) and vertical A14 BPM sum signal (blue).

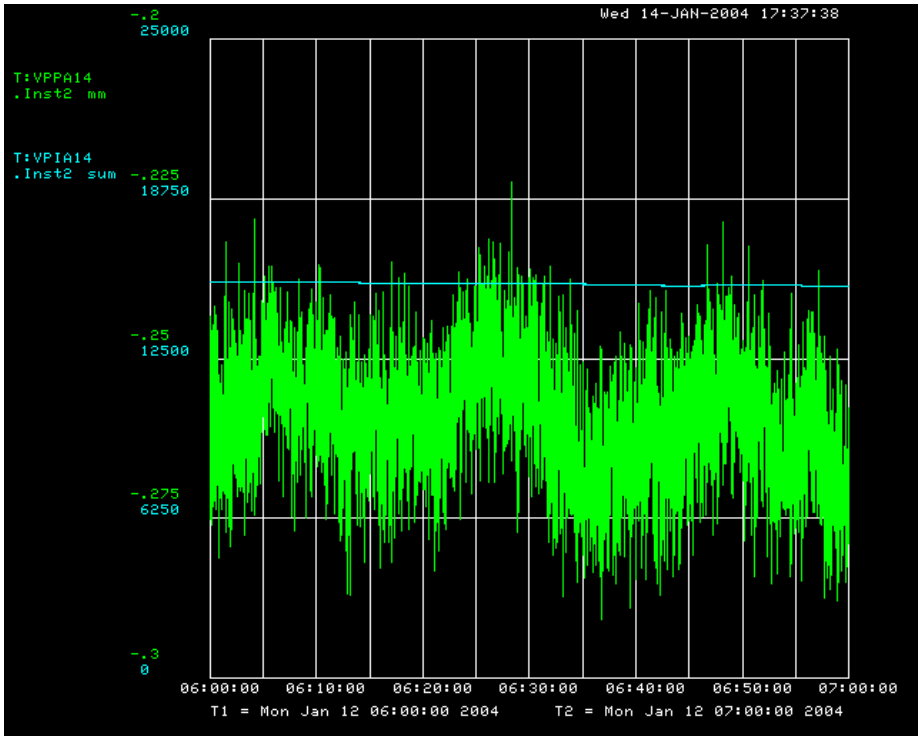

Figure 5. One hour of data, 20 hours into the store. Vertical A14 measured position (green, 25 microns/div.) and vertical A14 BPM sum signal (blue).

Data Standard Deviation	First one-hour interval	Second one-hour interval
Full one-hour period	0.0165 mm	0.0100 mm
5 min. interval #1	0.0084 mm	0.0092 mm
5 min. interval #2	0.0097 mm	0.0077 mm
5 min. interval #3	0.0076 mm	0.0088 mm
5 min. interval #4	0.0093 mm	0.0088 mm
5 min. interval #5	0.0082 mm	0.0089 mm
5 min. interval #6	0.0083 mm	0.0083 mm
5 min. interval #7	0.0083 mm	0.0105 mm
5 min. interval #8	0.0083 mm	0.0086 mm
5 min. interval #9	0.0076 mm	0.0095 mm
5 min. interval #10	0.0091 mm	0.0088 mm
5 min. interval #11	0.0085 mm	0.0097 mm
5 min. interval #12	0.0084 mm	0.0094 mm
Average of 5 min. intervals	0.0085 ± 0.00061 mm	0.0090 ± 0.00072 mm

Table 1. Standard deviations of position data from two one-hour periods, one early and one late in store.